

**BINDURA UNIVERSITY OF SCIENCE EDUCATION
DEPARTMENT OF ENVIRONMENTAL SCIENCE**

**AN ANALYSIS ON THE IMPACT OF TECHNOLOGY INTRODUCTION ON
SAFETY, HEALTH, ENVIRONMENT AND QUALITY MANAGEMENT. A
CASE OF EMERGING TRENDS AND INNOVATIONS, HARARE.**



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***A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
OF THE BACHELOR OF SAFETY, HEALTH, AND ENVIRONMENTAL MANAGEMENT.
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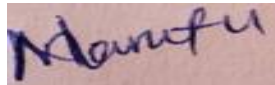
Date: June 2025

DECLARATION

To be compiled by the student

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I, Natasha Nyaradzo S Marufu hereby declare that this work is entirely the product of my findings and has never been presented to any academic institution. Any reference to previously published work has been indicated.



23 July 2025

Signature of the student.....Date.....

To be compiled by the supervisor

This dissertation is suitable for submission to the faculty and has been checked for conformity with the faculty guidelines.



23 July 2025

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ABSTRACT

Background: This research investigates the impact of technology introduction on Safety, Health, Environment, and Quality (SHEQ) management within the construction industry, focusing on emerging trends and innovations in Harare. These technological advancements aim to improve Safety, Health, Environment, and Quality (SHEQ) management by reducing hazards, enhancing compliance, and ensuring better project outcomes. However, the successful adoption of these innovations depends heavily on effective implementation and adequate training of personnel. In the context of Harare's rapidly developing construction industry, exploring how these emerging technologies influence SHEQ management can provide valuable insights into best practices and potential challenges, ultimately contributing to safer, healthier, and more sustainable construction environments.

Materials and Methods: Employing a purposive sampling approach, 40 participants from five construction companies were selected to provide insights into technological integration and its effects using surveys. The study examines how technological innovations influence SHEQ outcomes.

Conclusion: Findings reveal that when effectively adopted and staff are properly trained, technology significantly enhances safety protocols, health standards, environmental sustainability, and quality management. The study underscores the potential for technological innovations to transform SHEQ practices, emphasizing the importance of strategic implementation and capacity building for optimal benefits.

Key terms: technology, innovations, safety, accidents

DEDICATION

This research is dedicated to my mom (Tsitsi Farirayi), with love and gratitude, for her unwavering support and inspiration.

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LIST OF ACRONYMS

SHEQ	Safety, Health, environmental and quality management
BIM	Building Information Modeling
AI	Artificial Intelligence
QMS	Quality Management Systems
GIS	Geographic Information systems
VR	Virtual Reality
AR	Augmented Reality

CHAPTER 1: INTRODUCTION

1.1 Introduction to the Study

Advancements in technology usage in safety, health, environment, and quality (SHEQ) management have emerged as one of the critical drivers influencing industrial evolution globally. New technologies have greatly transformed workplace safety and operational productivity. This chapter therefore offers an introduction to the study by highlighting its importance and the area of focus. The introduction provides an overview of this potential and the role of technology in it, while the background section provides an historical overview and analysis of the state of SHEQ management. Following sections, describe the scope and the aims of the study, research questions and hypothesis that forms a background to the subsequent elaborated analyses.

1.2 Background of the Study

The fields of Safety, Health, Environment, and Quality Management (SHEQ) have evolved significantly over the past few decades. This evolution has been driven by various factors, including technological advancements, regulatory changes, and the increasing awareness of the importance of sustainability in business practices. This essay will provide a comprehensive background on the development of SHEQ management systems, starting with Europe and then moving to Africa, South Africa, and finally Zimbabwe. The analysis will include relevant research studies that highlight the trends, challenges, and innovations in SHEQ management across these regions.

Europe has long been at the forefront of SHEQ management practices. The European Union (EU) has established stringent regulations aimed at protecting workers' safety and health while promoting sustainable environmental practices. The evolution of SHEQ management in Europe can be traced back to the early 20th century when industrialization led to increased workplace accidents and health issues. In the aftermath of World War II, Europe experienced rapid industrial growth, which brought about significant safety and health challenges. The establishment of the European Agency for Safety and Health at Work (EU-OSHA) in 1996 marked a significant milestone in promoting workplace safety across member states (EU-OSHA, 2020). The agency has since played a crucial role in fostering a culture of prevention and risk assessment in workplaces throughout Europe.

Recent technological advancements have further enhanced SHEQ management practices in Europe. For instance, the integration of data analytics and artificial intelligence (AI) into risk assessment processes has allowed organizations to identify potential hazards more effectively (Bertolini et al., 2021). Moreover, the adoption of digital platforms for incident reporting has improved communication and accountability within organizations (Bertolini et al., 2021). Several studies have explored the impact of technological innovations on SHEQ management practices in Europe.

For example, a study by (Kelm & Meins-Becker, 2019) on the application of the BIM method and use of RFID technology and Augmented Reality to improve work safety in the German construction sites. Their aim was to show a decrease in accidents and injuries after the application of the BIM technology. The result only presented that the technologies implemented enhanced safety in workplaces where as this study will not only identify the impact of the technologies but also evaluate challenges and barriers faced in integrating these technologies effectively into the SHEQ management.

Another comprehensive review of visualization technology such as augmented reality and how they have been implemented in the construction sector by (Guo et al.,2017), showed that there are implementation barriers in the wider industry. Some of the barriers included insufficient standardization. Lack of standardization of the augmented data and processes impeded the integrated of safety management. Similarly, a study by (Tay et al.,2017) on 3D printing summarized the challenges of effectively implementing these technologies to improve SHEQ management.

These studies also presented the ability of the BIM and augmented reality technologies to detect hazards before they happen. One example of this is struck-by accidents which in 2015, 9 358 accidents were recorded in the UK construction industry between 2001 and 2011 (Chi et al., 2015). Use of these analytics is therefore highly recommended in the UK as they uncover patterns to make informed predictive based safety (PBS) to pinpoint potential risks and proactively them. According to the Engineering news record, the results for PBS are astounding with early adopters seeing incident rates drop by 50% over a year (Grace Ellis (2022)).

According to existing research, new technologies could be used to maximize worker safety in the construction industry. Nonetheless, there has been little uptake of safety solutions in the building sector. Lack of knowledge about reducing the risk of unsuccessful adoption could be one factor in the limited uptake of safety technologies (Ali Karakhan, 2019). Workplace accidents have long been linked to the advancement of technology in manufacturing processes and labor procedures, according to a case study that examined seven industrial enterprises in the United States.

Human beings believe that machines could reduce occupational safety and health problems, which is blind faith (D Harrison 2003). His study also reviewed that adoption of new technologies can pose more accidents if not properly implemented. No technological innovation automatically reduces accidents and injuries in the workplace, innovations must be accompanied by appropriate knowledge and supported by regulatory mechanisms (Capentier-Roy et al., 1998). The impacts of technology adoption in SHEQ management remain debatable.

Technology can improve workplace safety, but it can also create new hazards. Increased use of robotics and autonomous vehicles, including drones, can help lower work-related injuries by up to 11% by 2030, according to another study conducted in Canada by Cameron et al. (2018). Drones and robotics, according to Cameron et al. (2018), can handle tedious, repetitive jobs in addition to enabling workers to avoid hazardous circumstances. As a result, employees may remain more vigilant throughout the workday and reduce the possibility of accidents brought on by inattention or exhaustion.

Over the past 20 years, there has been a significant increase in interest in using technology as a preventive measure to reduce the disproportionately high rate of worker fatalities and injuries in the construction industry when compared to other industrial sectors (C. Nnaji, 2020). The administration of occupational health and safety will be impacted by the new paradigm shifts brought about by the fourth industrial revolution, or Industry 4.0 (A. Badri, 2018). Industry 4.0, or I4.0, is a new paradigm for manufacturing that heavily relies on technology and has a significant effect on labor and employees.

However, it is unclear how the deployment of I4.0-related technologies would affect safety and occupational health (R. Zorzenon, 2022). The risks will increase and OHS will suffer if the

technologies propelling industry 4.0 development in industrial businesses' projects are dispersed and separated (Bryan Boudreau-Trudel, 2018).

The landscape of SHEQ management in Africa is characterized by diverse challenges and opportunities. While some African countries have made significant strides in improving safety and health standards, others continue to grapple with high rates of workplace accidents and environmental degradation. Historically, Africa's industrial development has been hampered by economic instability, inadequate infrastructure, and limited regulatory frameworks. However, the adoption of international standards such as ISO 45001 (Occupational Health and Safety Management Systems) has prompted many organizations to prioritize SHEQ management (International Organization for Standardization [ISO], 2018).

Emerging technologies are beginning to transform SHEQ management practices across Africa. Mobile applications for incident reporting and health monitoring are gaining traction, particularly in industries such as mining and construction (Mabasa et al., 2020). These technologies enhance communication and facilitate timely responses to safety concerns. The downstream petroleum industry in Ghana is one among many sectors characterised by the convergence of the numerous hazardous exposures that can potentially cause serious catastrophe and work-related accidents (University of Cape Coast, 2023).

A study on the application of artificial intelligent technology to enhance safety practices in the downstream petroleum industry in Ghana was carried by (P. John, 2023). The results of the study showed that the AI technology can be reduce some of the OHS and not all of them, for example it helps in predictive analytics of the environment and cyber security.

In 2015, Bollore a transport and logistics company that operates in some of the countries in Africa including Cote d'Ivoire, Senegal and Nigeria implemented the use of automated guided vehicles (AGVs) and automated cranes (Smith, 2020). According to Smith (2020), the machines enhanced safety as they improve precision of load handling thus reducing the risk of accidents caused by human error during lifting operations. However, despite the advantages, Smith (2020) also mentioned the potential risks associated with the automated machines.

For instance, collision risks where the cranes are likely to collide with workers if not properly monitored. Another risk mentioned was electrical shock, if machines are not properly installed or maintained. Therefore, adoption of these automated technologies requires workers to adapt to new operational protocols. Various companies in African countries are increasingly implementing different technologies to increase productivity and efficiency. Sasol Limited, a global integrated chemicals and energy company headquartered in South Africa, has been at the forefront of adopting advanced technologies.

According to research conducted by Muller and Maritz (2021), the company introduced the ‘SHEQ Mobile App’ which allows employees to report incidents, access safety protocols as well as receive real-time updates on safety trends. Sasol limited also introduced the use of drones for site inspections (Sasol, 2020). The research only stated the success of the technologies in decreasing workplace incidents by approximately 25% over a two-year period after implementation. The research, however, did not outline the possible risks posed by the implementation of the SHEQ Mobile App as well as the drones.

SHEQ management in Zimbabwe has followed the international trends, although the local socio-economic and industrial factors have consequently influenced the changes. In the past, occupational safety practices in Zimbabwe were primitive involving manual work and weak legislation. When globalization processes increased in the late twentieth century, it started implementing international standards for SHEQ management despite doing so at a slower rate than what developed countries were doing (Gudmundsdottir & Rafnsdottir, 2004).

Gradually in the 1990s the Zimbabwe construction and manufacturing industries adopted use of automated machinery. Although this change eliminated the physical demands of handling parts, it created new hazards related to equipment operation and repair (Bresnahan et al., 1999). For instance, lack of proper training when using items such as bulldozers and cranes mostly resulted in mishaps, a factor that called for proper training in safety measures (Ratna & Kaur, 2016).

Industries around the world have integrated technology to improve their SHEQ results. In the United States, the adoption of safety technologies such as digital safety systems resulted to a less workplace incidence rate by 20% in the last fifteen years (2000-2015) (Accenture, 2018). However, the advancement stagnated after 2015 which led the industry to focus on wearable devices and AI-based monitoring systems. Such technologies have been found to work well in high-risk areas like mining,

where the identification of existing dangers in real-time has given so many people a second chance at life (Halse, 2021).

However, the use of such technologies in Zimbabwe has been rather limited. In their 2023 safety report of the City of Harare, there are recurrent issues such as lack of adequate training and lack of resources. These injuries included one fatal electrocution during bulldozer operations occasioned by negligence and lack of precautionary measures. This case can be viewed as an example of more significant issues related to the practice of SHEQ standards implementation (Mardonova & Choi, 2018).

In 2019, Delta Corporation adopted the Automated Quality Control System as part of its commitment to enhancing product quality and operational safety. The AQCS utilizes sensors and real-time data analytics to monitor production processes, ensuring that quality and safety standards are maintained consistently (Chikanda, 2021). According to a report by Chawira and Nyoni (2020), the AQCS enabled Delta to automate critical monitoring processes that were previously conducted manually, reducing human error and improving operational efficiency.

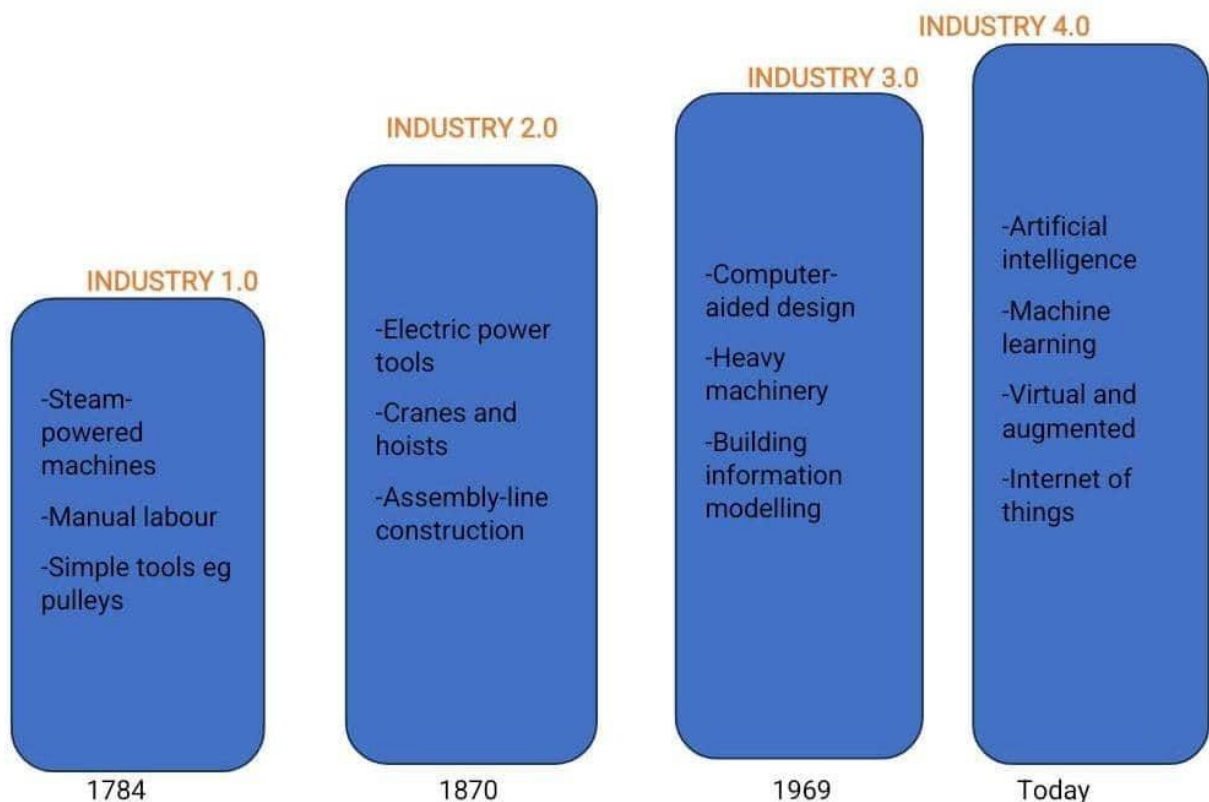
The implementation of the Automated Quality Control System at Delta Corporation has resulted in significant improvements in SHEQ management. The system not only enhanced product quality and safety but also contributed positively to environmental sustainability. While there were challenges related to employee training and resistance to change, the long-term benefits have justified the investment in new technology. Delta Corporation's experience exemplifies how technology adoption can effectively transform SHEQ management practices in the manufacturing sector (Chikanda, 2021).

The nature of SHEQ management in Zimbabwe is compounded by the prevailing socioeconomic environment. Lack of funds and specialized knowledge prevent the use of modern technologies on a large scale. However, culture in regards to safety and technology factors greatly influence organizational practices (Vintangcol, 1999). Solving these problems needs policy, capacity and community interventions that can be achieved through policy change, capacity development and community mobilization. There are therefore research gaps in the Zimbabwe SHEQ environment. Although

literature research from other countries focuses on how the use of technology enhances workplace safety, little has been done regarding the Zimbabwean context.

This research seeks to address this gap through evaluating the effects of technological advancements on SHEQ management in the socio-economic and industrial environment of Harare (Ratna & Kaur, 2016). Finally, this paper shows that the changes in SHEQ management in Zimbabwe are a result of a blend of global trends and a nation's experience. As with any technological innovation, there is significant potential in implementing technology solutions but doing so presents several systematic issues and contextual complexities. This research aims at joining this discourse by presenting scientific findings and suggestions.

Figure 1.2 shows Evolution of Technology in Industries



1.3 Problem Statement

The use of innovation in the construction industry in Harare has brought about new opportunities and risks in SHEQ management. Hybrid machinery, polystyrene blocks, and polymer stabilizers that help increase productivity and decrease the negative impact on the environment have been invented, but the unsafe application of these inventions has been a major concern. For example, in 2023, the City of Harare recorded over five injuries and two fatalities as a result of workers being run over by these machines.

National Social Security Authority (NSSA) compensated for all workers who were eligible with full coverage except for one case where a worker was electrocuted after the bulldozer came into contact with electrical power lines as a result of alcohol influence. It was ruled out as contributory negligence. The organization recorded high lost time injury in 2023 as workers had to stop reporting to work until they had recovered. These accidents do not only pose risks to the welfare of employees, but they also create business losses, declined company reputation, and lower productivity. It is therefore very important to evaluate the impacts of technologies adopted by the City of Harare on SHEQ management, for instance, polystyrene blocks and polymer stabilizers. Furthermore, this study will help identify as well as provide solutions to potential risks associated with the introduction of new technology at the City of Harare Municipality.

1.4 General Objective

To evaluate the impact of technological innovations on safety, health, environment, and quality (SHEQ) management in the construction sector of Harare, identifying gaps and opportunities for enhanced implementation and integration.

1.4.1 Specific Objectives

- To identify the technological innovations currently employed in the construction sector of Harare.
- To assess the effects of these technologies on safety, health, environmental, and quality outcomes.
- To evaluate the challenges and barriers faced in integrating these technologies effectively into

SHEQ management.

- To propose evidence-based strategies for improving SHEQ management through optimized use of technology.

1.5 Research Hypothesis

H₀

The technological innovations within City of Harare have a great impact on Safety, Health, and Environmental Management.

H₁

The adoption of new technologies in the construction sector of City of Harare does not have any impact on Safety, Health, Environment, and Quality (SHEQ) management.

1.6 Justification of the Study

The City of Harare construction department is increasingly adopting technology as it grows. Studying the impacts of these adopted technologies can help enhance workplace safety. Understanding potential hazards associated with the new technologies can facilitate pro-activeness that is City of Harare will be able to implement effective safety measures and improve their emergency preparedness and response. Effective safety measures and emergency leads to reduction in workplace injuries, fatalities, lost time injuries and injury related costs at City of Harare.

This will enhance overall productivity of the organization hence, protecting its reputation and gaining competitive edge. Analysing effects of the technology can help identify skill gaps and inform training programs ensuring employees are equipped to use new tools effectively. Better training and improved tools results in quality products which then enhances customer satisfaction. The study can also benefit other construction companies as they can benchmark against best practices adopted by City of Harare to enhance their own operations.

Implementing sustainable technologies can lead to creation of new products or services expanding market opportunities for all companies within the construction industry. This improves quality and safety

standards which enhance productivity and competitiveness of industries, supporting NDS1(2021-2025) which focuses economic stability, industrialization, technology adoption, and social development. As companies adopt technologies that promote productivity, it can lead to the overall economic growth of Zimbabwe as it contributes to higher gross domestic product (GDP), hence the study aligns with Zimbabwe's vision 2030 which aims to transform Zimbabwe into upper-middle-income country with sustainable development and improved quality of life.

The technological advancements can create new industries and job opportunities, shifting the workforce towards higher skilled positions and reducing unemployment in the country. These technological innovations, if effectively adopted can help inform national sustainability initiatives, helping reduce Zimbabwe's carbon footprint and address climate change issues. Understanding the effects of these technologies can help policy makers in Zimbabwe as well as other countries to develop evidence-based regulations that can address real technological issues.

Technology evolves rapidly and can also become outdated easily; this research can therefore help policy makers to keep pace with changes and adjust regulations accordingly. Globally, the study can help boost productivity on a worldwide scale, contributing to global economic growth and prosperity. Innovations aimed sustainability can reduce global environmental impacts such as climate change, pollution and resource depletion supporting the MDG7 (Ensure Environmental Sustainability). As technology becomes more widespread, it can help bridge economic gaps by providing access to resources, education, and opportunities in developing region. This study can therefore be life changing worldwide.

1.7 Study Area

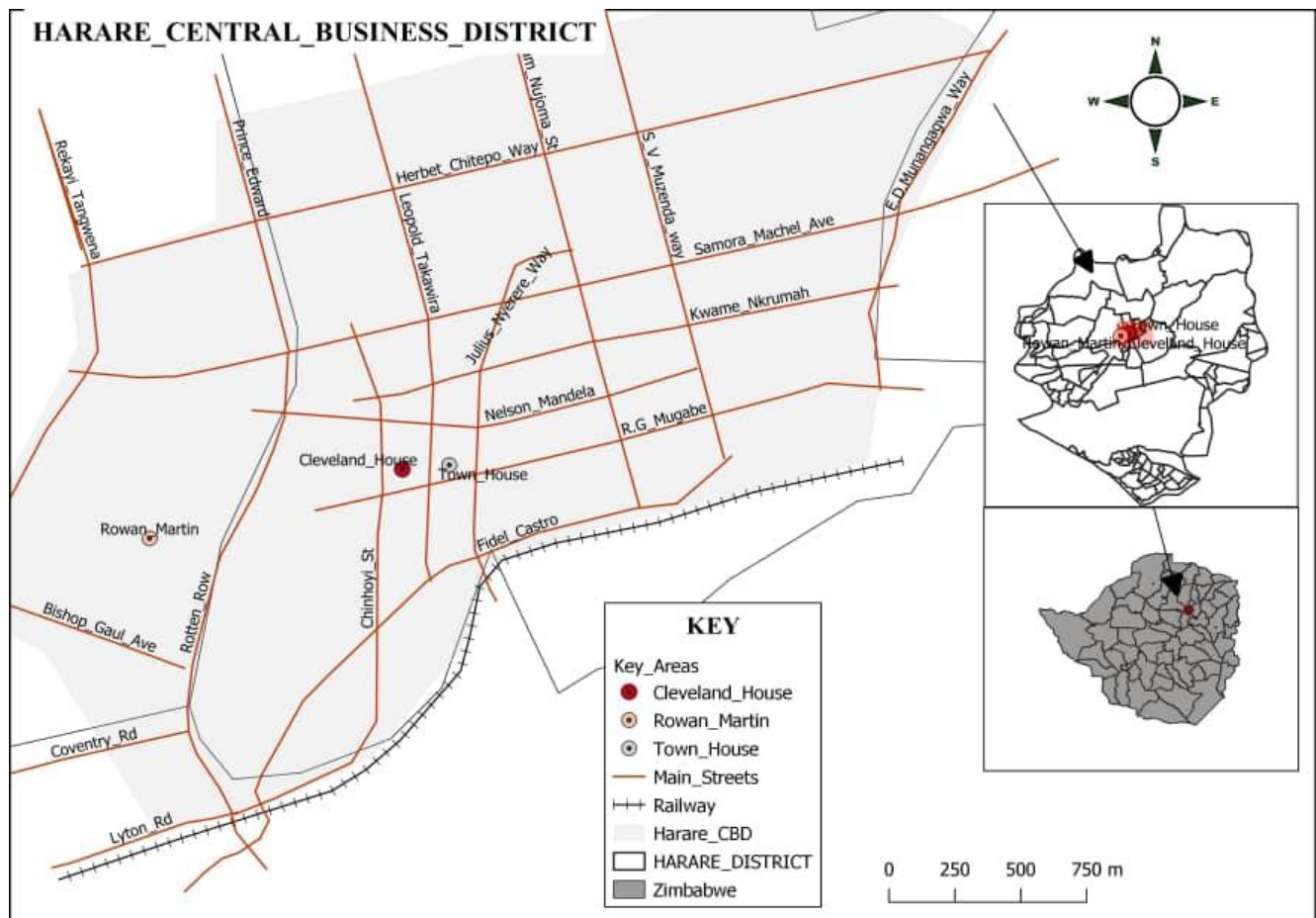


Fig1.7.1 shows study area map

The administrative organization in charge of serving the citizens of Zimbabwe's capital, Harare, is the City of Harare Council. Housing and community services, finance, health services, Harare water, and works are among the departments that make up the City of Harare council. The City of Harare council is in charge of housing and lodging, garbage collection facilities, health services, and clean and safe drinking water, among other things. The upkeep and improvement of the city's infrastructure fall within the purview of the Works department. Zimbabwe's capital, Harare, is located in the northeastern region of the nation. The city is tucked away in the Harare Valley in the Mashonaland area of northeastern Zimbabwe. Geographically, Harare is positioned at 17.8278° S latitude and 31.0535° E longitude. The city's elevation ranges from 1,400 to 1,540 meters above sea level, with an average elevation of 1,482 meters (Moyo. 2018).

The City of Harare, is a vibrant urban centre characterized by a diverse population and complex socio-economic dynamics. As of the latest estimates, Harare has a population of approximately 1.6 million

people, making it one of the largest cities in the country (Chikozho, 2020). The population is composed of various ethnic groups, primarily Shona, along with Ndebele and other minority communities. The demographics of Harare reflect a youthful population, with a significant proportion under the age of 35, which influences social dynamics, employment patterns, and economic activities.

In terms of gender dynamics, Harare exhibits both traditional and progressive elements. Women play a crucial role in the informal economy, engaging in activities such as street vending, small-scale farming, and artisanal crafts. Despite facing challenges related to gender inequality, including limited access to formal employment opportunities and education, women in Harare are increasingly becoming entrepreneurs and contributing to household incomes. However, gender-based violence and discrimination remain pressing issues that affect women's ability to thrive economically and socially (Chikozho, 2020).

The socio-economic state of Harare is marked by significant challenges, including high unemployment rates, inflation, and economic instability. The formal job market has shrunk considerably over the years due to economic downturns and political instability, leading many residents to rely on informal employment for their livelihoods. Informal sectors dominate the economy, with many individuals engaging in micro-enterprises or casual labour. This economic landscape has resulted in a vibrant but precarious environment where survival often depends on adaptability and resilience.

Residents of Harare typically survive through a combination of informal trading, remittances from family members abroad, and subsistence farming on small plots within the city or in peri-urban areas. Many households engage in multiple income-generating activities to mitigate risks associated with economic volatility. For instance, it is common for individuals to combine street vending with part-time jobs or engage in community-based projects that provide additional income (Mabasa et al., 2021).

Access to basic services such as water, sanitation, and healthcare remains a challenge for many residents of Harare. The city's infrastructure has struggled to keep pace with population growth, leading to issues such as water shortages and inadequate waste management. These challenges disproportionately affect low-income communities, exacerbating health risks and impacting overall quality of life. Community health initiatives and non-governmental organizations play a vital role in addressing some of these gaps by providing essential services and support to vulnerable populations.

Education is another critical aspect of life in Harare. While there are numerous educational institutions ranging from primary schools to universities, access to quality education can be uneven. Families often face financial constraints that hinder their ability to pay for school fees or related expenses. However, there is a strong cultural emphasis on education as a pathway to upward mobility, leading many families to prioritize educational attainment despite economic hardships.

Harare's subtropical highland climate, characterized by mild winters and warm summers, makes it an attractive destination for residents and tourists alike. The city's average temperature is 18°C, with average annual rainfall of 825 mm. This favourable climate, combined with its strategic location, makes Harare a vital centre for Zimbabwe's economy, culture, and politics (Graham and Heath 2019).

Harare is also involved in activities relating to finance, real estate, manufacturing, healthcare, education, art, culture, tourism, agriculture, mining, and regional affairs.

In summary, the City of Harare is a dynamic urban centre grappling with a range of socio-economic challenges. The interplay between population dynamics, gender roles, and economic survival strategies shapes the daily lives of its residents. While informal employment dominates the economic landscape, community resilience and adaptability are key themes that characterize life in this bustling city. Continued efforts to address gender disparities, improve access to essential services, and promote sustainable economic development are crucial for enhancing the well-being of Harare's population in the years to come (Akinboade et al., 2022; Chikozho Mungai, 2020).

1.8 Limitations of the Study

This dissertation is to provide valuable insights on the impact of introduction of technology on the safety, health, and environmental quality management of City of Harare. However, there are limitations to the study that may include time constraints. This study is being carried out over a short period of time; therefore, this may hinder understanding of trends as well as long term impacts of the technology on safety, health, and environmental management.

Access to data is also another limitation. Accessing data in the organization can be difficult as some reports related to safety and health performance can be confidential. Lack of access to the data can limit the depth of the analysis hence affect the conclusions of the study. Looking at specific technologies of the organization's construction and infrastructure department may overlook the influence and effects of technologies adopted by other departments thus also limiting the outcome of study.

Another limitation is technology variability. With the rapid evolving and adoption of technology, the study can only be valid for a short period of time. As other technologies come into play, this study may easily become outdated. Moreover, this study focuses on the construction sector of City of Harare, therefore, this affects the generalizability to other cities or rather countries. The study, however, adopts various rigorous techniques to improve the validity and reliability of the study findings in order to make a useful contribution to the existing literature.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

According to McCombes (2019), a literature review is an examination of scholarly sources on a particular subject that gives the researcher a sense of the state of the field and helps them to pinpoint relevant concepts, approaches, and knowledge gaps. In scholarly literature, the idea of technological innovations has been introduced in a number of ways. Rapid industrialization has accelerated the adoption of technology as a means of cutting labor and operating expenses and maintaining market leadership. However, the effects of these technologies on SHEQ management are still up for debate and have been the subject of ongoing studies.

A variety of academic publications about the effects of technology advancements on SHEQ management in workplaces will be assessed in the current study. According to its objectives, the study's focus is on how technology adoption affects SHEQ management; as a result, the literature review is focused on this topic, highlighting the dangers of new technologies and the significance of assessing the difficulties in successfully integrating them. The main goal of this chapter is to improve theoretical and practical knowledge of how technology affects environmental, health, and safety management.

2.2 Overview of Technology in Construction SHEQ Management.

Because of the high rates of fatalities and injuries in the construction industry, there has been a lot of recent research on the need to improve worker safety. Several control strategies, such as the use of technology, have been implemented to enhance construction workplace safety performance in an effort to lessen this scourge. various technologies. Safety management procedures have been completely transformed by the introduction of digital tools like sensors, Building Information Modelling (BIM), and Internet of Things devices.

For example, Azhar et al. (2012) interviewed project managers and safety officers as part of a qualitative case study analysis of BIM adoption in a number of construction projects in the UK. According to the study, BIM improves risk assessment and hazard visualization, which in turn improves safety planning and communication. Additionally, it demonstrated a correlation between the adoption of BIM and a decrease in unsafe practices.

Similar to this, Zhang et al. (2019) conducted a field study using Internet of Things sensors on Chinese construction sites, gathering safety and environmental data in real time over a six-month period. Accidents and environmental infractions decreased by 25% as a result of the IoT sensors' ability to provide real-time alerts for dangerous situations. Therefore, Zhang et al. (2019) came to the conclusion that sensor technology, through ongoing monitoring, promotes proactive safety and environmental management.

Robotics and automation were also used in the construction industry. Choi et al. (2017) conducted a case study on the analysis of robotic demolition operations in South Korea and found that robotics can greatly enhance environmental compliance and safety standards, particularly in hazardous tasks where workers are exposed to less dust, noise, and hazardous materials. A 40% decrease in safety incidents was also measured by the study.

Additionally, machine learning and artificial intelligence (AI) have started to influence SHEQ management. Using past project safety data from several US construction companies, Li et al. (2021) created and verified machine learning models. employed classification and regression algorithms to forecast safety hazards. The models predicted high-risk activities with over 85% accuracy, allowing for focused interventions and a 20% estimated reduction in safety incidents.

Nevertheless, not every technology that industry workers have embraced for safety management has worked as intended or shown itself to be successful. Crucially, industry participants must assess how prepared they are to embrace safety technologies (John Gambatese, 2020). Ali Karakhan's 2019 study used a combination of an expert panel and a literature review to identify and categorize 26 technology adoption predictors. The Relative Importance Index was used to rank the degree of influence for each safety technology adoption predictor that was identified.

When the study participants were grouped based on work experience and company size, analysis of variance was also done to evaluate any possible differences in the predictors' perceived level of importance. Twelve of the 26 predictors that were found to have a significant impact on construction companies' decisions to adopt new technologies are statistically significant. Reliability, efficacy, and durability of technology were found to be the most significant predictors.

Figure 2.2 shows Modern Technologies in Construction Industries



2.3 Safety and Health Outcomes Through Technology

Technology use improves safety procedures, according to research. In the United States, Johnson and Lee (2019) assessed the impact of wearable safety devices using a mixed-method approach that included worker surveys and safety incident reports. They discovered that wearable technology increased safety performance by enhancing hazard awareness and reporting. Similar to this, Zhang et al. (2018) monitored control and experimental groups for three months during a controlled field trial involving wearable safety devices on Chinese construction sites.

Due to real-time alerts and improved adherence to safety procedures, workers who wore wearable technology showed a 30% reduction in injuries. Research from Europe has demonstrated that health monitoring technologies, such as Internet of Things (IoT) devices measuring worker health parameters, can identify early indicators of occupational illnesses and enable prompt interventions (Kumar et al., 2020). They used a quasi-experimental design to compare health outcomes in textile factories before and after the introduction of new technology.

Love et al. (2018) found that digital safety training improves safety awareness and behaviors after surveying 150 construction workers in Australia before and after digital safety training modules, analyzing safety compliance and incident rates. According to his research, incident rates dropped by 20% and safety compliance rose by 15% after training. Additionally, Li et al. (2020) used environmental sensors and remote monitoring systems from several projects in China to analyze health-related outcomes like respiratory illness.

A 25% decrease in respiratory illnesses was linked to real-time environmental monitoring, which decreased workers' exposure to dust and other pollutants. This suggests that remote environmental monitoring can enhance worker health. In Africa, a small but expanding body of empirical research has started to document how technology affects SHE and quality management. Based on safety audits and employee surveys, Ojo et al. (2021) in Nigeria examined the implementation of automated safety systems in oil and gas companies and found notable increases in safety compliance and incident reduction.

Zimbabwe-specific research is still rare but is starting to appear. Chimedza and Nyoni (2020) interviewed manufacturing SMEs in Harare as part of a qualitative study to find out how they felt about technological advancements like digital inventory systems and mobile-based safety reporting. Although obstacles like infrastructure deficiencies and training requirements still exist, their findings point to beneficial effects on safety monitoring and process quality.

2.4 Environmental and Quality Outcomes Through Technology.

In recent years, the relationship between technology and the environment has attracted a lot of attention, and a growing corpus of literature has examined the intricate dynamics at work. In Spain, Martinez et al. (2017) assessed the use of green manufacturing technologies and observed decreases in waste production and emissions. Lifecycle assessments, emission measurements, and environmental audits were all part of their strategy. Another study combined environmental sampling data with spatial analysis to use GIS-based environmental impact assessment in a number of construction projects in Singapore (Luo et al., 2015).

GIS integration improved site planning, resulting in a 20% decrease in pollution and land disturbance incidents (Luo et al., 2015). Sustainable site management is supported by GIS tools. Cities can make their environments more livable, efficient, and sustainable by combining GIS with other technologies. Kibert (2016) conducted another case study on green building initiatives in Europe, evaluating the uptake of environmental technologies. Utilizing environmentally friendly materials and waste tracking technologies, the research produced quantifiable decreases in waste production and carbon emissions. Consequently, Kibert (2016) came to the conclusion that digital tracking encourages environmentally friendly building methods.

Improved product quality and process efficiency have also been associated with the use of digital quality management systems (QMS), such as ERP and IoT-based tracking. Based on statistical analysis of defect rates and customer feedback, Nguyen and Tran (2019) in Vietnam conducted case studies of manufacturing firms and found that digital QMS increased customer satisfaction and reduced defects.

Digital platforms improve quality assurance and control by improving defect detection by 35% and lowering rework costs by 20%, according to case studies of digital Quality Management Systems (QMS) implementation across construction projects in Singapore, which were supplemented by project manager interviews. Chen and Lu (2018) found that timely corrective actions were made possible by real-time data. Additionally, Moyo (2019) used a case study methodology to examine the use of environmental monitoring technologies in Zimbabwe's mining industry.

Based on environmental audit reports collected over a three-year period, the study discovered that remote sensing and GIS tools enhanced environmental compliance and reporting accuracy. Kim et al. (2019) used drone inspections to evaluate structural quality in South Korea, comparing the results of drone surveys with traditional manual inspections over a six-month period in order to assess the impact

of drones on product quality. Drones detected structural problems 50% more quickly and accurately, which resulted in early repairs and increased safety, which in turn led to improved quality control efficiency

2.5 Disparities in Existing Literature

Even though the empirical literature on how technological advancements affect safety, health, environmental, and quality outcomes in a variety of sectors worldwide is expanding, there are still a lot of unanswered questions about how these dynamics relate to Zimbabwe's construction sector, especially in Harare. There is a noticeable lack of sector-specific data on how construction companies in Harare are implementing and integrating emerging technologies into their SHEQ management systems because the majority of previous studies concentrate on the manufacturing or industrial sectors in Africa.

A thorough grasp of the technological landscape and its efficacy is thus hampered by the paucity of empirical data describing the actual technologies currently used in the local construction landscape. Additionally, while research from around the world generally shows that technology improves SHEQ outcomes, there is a lack of local data showing whether these benefits apply similarly to construction projects in Zimbabwe, taking into account particular organizational, regulatory, and infrastructure challenges.

By evaluating the true impact of these technologies on safety, health, environmental sustainability, and quality outcomes specifically within Harare's construction sector, this study can close a significant evidence-based knowledge gap. In addition to recognizing the effects, the literature shows that Zimbabwe has not sufficiently examined the difficulties and obstacles encountered when incorporating new technologies into SHEQ management.

Current research frequently highlights regulatory gaps, resistance to change, skills shortages, and infrastructure deficiencies, but it lacks specific, context-specific information about how these obstacles appear in regional construction companies. By carefully analyzing these issues, this study can offer a more nuanced understanding of the barriers to successful technology adoption. Furthermore, although some research indicates that integrating technology enhances results, few provide workable, empirically supported solutions that are adapted to Zimbabwe's particular socioeconomic and infrastructure circumstances. This is a significant gap that could make attempts to use technology to enhance SHEQ management ineffective or unsustainable in the absence of contextualized strategies.

The prevalence of theoretical or cross-sectional studies that overlook the long-term impacts of technology adoption is another significant flaw in the current literature. Construction projects are dynamic, and innovations' effects on SHEQ outcomes may change over time. However, there is a lack of longitudinal research evaluating whether initial gains are maintained and how continued technological use affects environmental, health, and safety practices over the long term.

In order to address this and provide a more comprehensive understanding of the long-term advantages or difficulties of technology integration, a framework for continuous assessment must be proposed. Finally, the majority of current research tends to overlook the significance of stakeholder engagement in favor of concentrating solely on technical or managerial viewpoints. Several stakeholders' perspectives and experiences—contractors, employees, regulators, and clients—must be taken into account in order to develop a thorough understanding of the obstacles, facilitators, and tactics. This gap can be filled by incorporating the perspectives of various stakeholders, which will result in a more comprehensive and useful understanding that can guide practice and policy.

2.6 Summary

By offering context-specific, empirical, longitudinal, and stakeholder-inclusive insights into the current state of technological innovations in Harare's construction industry, their impact on SHEQ outcomes, the difficulties encountered, and effective integration strategies, this study seeks to close these crucial gaps. This all-encompassing strategy will make a substantial contribution to the corpus of current knowledge and facilitate the creation of useful, locally relevant interventions based on evidence, ultimately improving SHEQ management through the most effective use of technology.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This section outlines the methods employed to evaluate the impact of technological innovations on Safety, Health, Environment, and Quality (SHEQ) management within the construction sector of Harare. The research aimed to identify technological innovations currently utilized in the sector, assess their effects on SHEQ outcomes, evaluate integration challenges, and propose strategies for optimizing SHEQ management in light of these technological advances. The methodology utilized a mixed-methods approach, combining both qualitative and quantitative research techniques to provide a comprehensive analysis.

3.2 Research Design

A mixed-methods research design was adopted for this study, as it allowed for the integration of both quantitative and qualitative data collection methods. This approach provided a more holistic view of the research topic, ensuring that both the measurable impacts of the technologies and the experiences of workers and managers in the field were captured effectively. The research was conducted within the context of Harare's construction sector, specifically focusing on the use of innovations such as hybrid machinery, polystyrene blocks, and polymer stabilizers.

3.3 Population and Sampling

The study targeted the City of Harare construction workers and construction companies that usually collaborates with the City of Harare in the infrastructural development of Harare. Purposive sampling was used to select construction companies that are at the forefront of technological adoption since there are more likely to demonstrate significant impacts on SHEQ management providing valuable insights into effects of the new technologies. Five construction companies were selected for the study. The selection of five companies allows for the researcher to gather comprehensive qualitative and quantitative data. Focusing on smaller, manageable number of companies promotes in-depth investigation into each firm's specific practices and technological adaptations, and outcomes.

Working with a smaller sample also allows the researcher to conduct thorough data collection and analysis within the available resources that is funding and timeframe, ensuring the quality and accuracy of findings. Moreover, gaining access to company data, management insights and operational details can be challenging, limiting the sample to five companies. The companies were chosen based on their

willingness to participate, transparency and relevance, facilitating smoother data collection and enhancing the reliability of the information gathered.

The specific companies involved in the research included-

Table 3.3 companies selected for data collection

COMPANY	
1. Concrete Solutions Zimbabwe	Known for using hybrid machinery in their large-scale infrastructure projects. Strong safety culture with established SHEQ systems and certificates (e.g, ISO standards)
2. Harare Construction Ltd	A prominent player in the construction of residential and commercial buildings, utilizing polymer stabilizers in their building foundations. Recently adopted automated/robotic systems.
3. Exodus and Company Pvt Ltd	Specializes in eco-friendly construction, including the use of polystyrene blocks for insulation in building construction.
4. Elite Construction Co.	Known for its commitment to safety and environmental management, incorporating hybrid machinery into their heavy-duty construction projects.
5. Masimba Holdings Ltd	A company focused on sustainable construction practices, using both polymer stabilizers and polystyrene blocks. Data

For each selected company, between five and ten employees out of a hundred employees from each company were chosen to participate in the research, including both management personnel (such as SHEQ managers, project managers, and safety officers) and operational workers (such as machine operators and laborers). A minimum of five participants ensures sufficient diversity of opinions, experiences, roles related to safety, health, environment, and quality management whilst limiting to ten participants prevents data overload and maintains focus on key information.

This purposive sampling strategy ensured a balanced representation of both managerial perspectives on technology implementation and the experiences of workers who directly interacted with the technologies. A total of forty participants (from five construction companies) were selected to take part in the study. Within the potential pool of five hundred employees, it is important to choose key informants. Individuals who have direct experience and knowledge on the technological innovations were chosen.

Participants were purposively selected from different departments, roles, or levels with the companies. Focusing on forty participants is feasible within reasonable time and resource constraints, as well as help reach data saturation. Analyzing data from many participants maybe overwhelming and likely require different analytical approaches hence time consuming. In addition to surveys with employees, document analysis was also used to collect data. Documents included accident reports, safety audit records, and environmental impact assessments, providing additional insights into how technological innovations have influenced SHEQ outcomes in Harare's construction sector.

3.4 Data Collection Methods

Data collection was conducted through a combination of surveys and document analysis.

1. Surveys-

Surveys were distributed to employees at various levels within the selected construction companies. The surveys contained both closed-ended and open-ended questions to capture both quantitative and qualitative data. The questions were designed to assess the use of technology on construction sites, its perceived impact on safety, health, environmental, and quality outcomes, and the challenges faced by employees in adapting to new technologies.

2. Document Analysis-

Analyzing existing records such as accident reports, safety audits, and environmental impact assessments provided crucial background information on the implications of technological adoption in the construction sector. The analysis focused on trends in accidents, safety measures, environmental compliance, and the overall effectiveness of safety protocols. This provided valuable data on the practical effects of technology on SHEQ outcomes.

3.5 Data Analysis

1. Quantitative Analysis

Quantitative analysis involves the use of numerical data to quantify the relationship between technological innovations and their impact on SHEQ management. This type of analysis enables the researcher to test hypotheses, measure statistical significance, and present concrete numerical evidence to support conclusions. For the quantitative aspect, a survey questionnaire was used, which contained both closed-ended and Likert-scale questions. These questions focused on assessing-

The extent to which different technologies (e.g., hybrid machinery, polystyrene blocks, polymer stabilizers) have been adopted in the construction sector in Harare. The perceived effects of these

technologies on safety (e.g., number of accidents before and after technology adoption), health (e.g., decrease in health-related incidents), environmental outcomes (e.g., reduction in waste or pollutants), and quality outcomes (e.g., reduction in defects or rework). Also, the overall satisfaction with the integration of these technologies into SHEQ management practices was observed.

Since participants, including SHEQ managers, site supervisors, and workers, were asked to rate their experiences on a scale from 1 (strongly disagree) to 5 (strongly agree) or to report on a numerical scale (e.g., number of accidents, percentage decrease in waste, etc.).

Once the survey responses were collected, the data were processed and analyzed using descriptive statistics. This included frequencies to summarize how many companies or individuals adopted each technology. The mean, median, and mode calculations to determine the average ratings or responses across different SHEQ categories was calculated using SPSS together with bar charts and pie charts to visualize the distribution of technologies used by companies.

Trend analysis, especially where data was gathered across different periods, such as before and after the introduction of technology, to examine how accident rates, health issues, and environmental impacts have changed.

To validate the research hypotheses, statistical tests were conducted. In particular, ANOVA (Analysis of Variance) was employed to compare the differences in SHEQ outcomes before and after the adoption of technological innovations. For example, a t-test could be used to compare accident rates in the construction sector before and after the introduction of hybrid machinery. Tables and graphs, providing clear visual representations of key statistics such as the percentage of companies using certain technologies and the changes in SHEQ outcomes over time were put into place. Lastly, the statistical outputs, including p-values and confidence intervals, to indicate the significance of the findings.

2. Qualitative Analysis (Thematic Analysis)

Qualitative analysis was used to capture the richer, in-depth perceptions, attitudes, and experiences of stakeholders involved in the integration of technology in the construction industry in Harare. This approach allowed for a comprehensive exploration of how employees, managers, and other relevant stakeholders view the role of technology in SHEQ management, which quantitative data alone could not fully illuminate.

The discussions were designed to explore-

- The personal experiences of workers and managers regarding the effectiveness of new technologies in improving SHEQ management.
- The challenges faced by employees and SHEQ managers when integrating these technologies into daily operations.
- The perception of risks or accidents associated with the use of hybrid machinery, polymer stabilizers, and other innovative technologies.
- The benefits perceived by workers and managers in terms of productivity, safety, and environmental sustainability.

1. Familiarization with the Data- First, all the survey transcripts were thoroughly read and transcribed to familiarize the researchers with the content.

2. Generating Initial Codes- Key phrases, words, or segments related to SHEQ management and technological innovations were identified and coded. For instance, codes such as "safety concerns," "improved productivity," "environmental sustainability," and "training needs" were created based on the data.

3. Identifying Themes- The codes were organized into broader themes that reflect key issues related to technological innovations and SHEQ management. Common themes identified in this study might include the impact of technology on safety, how the adoption of hybrid machinery and polymer stabilizers has either improved or worsened safety. Also, the environmental impacts on how the new technologies help reduce waste and environmental harm in construction projects. Lastly, the training and knowledge gaps. The need for continuous training to address safety concerns and ensure effective technology use.

4. Reviewing and Refining Themes- After initial themes were identified, they were reviewed to ensure they accurately reflected the data. Then these themes were refined to avoid overlaps and ensure clarity.

5. Defining and Naming Themes- The finalized themes were clearly defined and named to reflect the main points that emerged from the data. For example, "Safety Concerns with Hybrid Machinery" and "Environmental Benefits of Polymer Stabilizers" would be such themes.

In the presentation of qualitative data thematic tables that summarize the frequency of certain themes and the number of participants who mentioned each theme were done

Table 3.5 Frequencies of themes

Theme	Frequency of Mentions	Example Quotes
Safety Issues with Hybrid Machinery	n/10	"There have been fewer accidents since we started using the hybrid machines, but there are still issues with machine malfunctions."
Benefits of Polymer Stabilizers for the Environment	n/10	"The polymer stabilizers are helping us reduce the carbon footprint and dust pollution during construction."

Direct Quotes from participants to provide depth and context to the identified themes. Quotes such as, "The hybrid machinery has made work faster, but safety concerns arise when it malfunctions" will be used to offer insight into the lived experiences of the construction workers. Illustrative Examples of how different companies are applying technology and managing SHEQ outcomes, based on the interview responses and case studies were done

3.6 Ethical Considerations

Throughout the entire research procedure, ethical considerations were closely followed. Every participant received comprehensive information regarding the study's goals, their part in it, and the intended use of their data. All participants gave their written agreement, guaranteeing that they were aware of their freedom to leave the study at any moment and without consequence. By anonymizing the data and making sure that any sensitive information like accident reports was handled with the highest care and security, confidentiality was preserved.

3.7 Conclusion

The research methodology employed a thorough and systematic approach to evaluating the impact of technological innovations on SHEQ management in Harare's construction sector. By utilizing mixed-methods research, including surveys, interviews, and document analysis, the study aimed to achieve its objectives of identifying key technologies, assessing their impact, and evaluating the challenges and

opportunities related to their integration into SHEQ practices. The results from this research will contribute to improving safety, health, environmental, and quality outcomes in the sector by providing valuable insights into the effective use of new technologies. The findings will help inform future policy and operational decisions in Harare's construction industry, ultimately fostering a safer and more sustainable environment for workers and the public

CHAPTER 4: DATA PRESENTATION

4.0 Results

4.1. Introduction

This chapter presents the key findings derived from the analysis of data collected during the research. It explores the effects of new technological tools and systems on the effectiveness and efficiency of SHEQ management practices. The results organized to highlight significant patterns, correlations, and insights that emerge from the responses of participants and observed data, offering a detailed overview of the technological impact within the context of SHEQ.

4.2. Demographic information

Table 4.2 Demographic data of participants

Items	Response	
	Frequency	Percent
Gender		
Female	18	45.0
Male	22	55.0
Age (years)		
18 -25	5	12.5
26-33	4	10.0
34- 41	7	17.5
42-49	12	30.0
50-57	7	17.5
58+	5	12.5
Experience (Years)		
1-3 years	4	10
4-6 years	16	40.0
Less than 1 year	5	12.5
More than 10 years	15	37.5

Results show that, majority of participants were males (55%) whilst female constituted the least (45%). Out of the 40 participants, 30% were in the age group (42-49) followed by those in the age group 34-41 years and 50-57 years respectively, these constituted 17% of respondents. Age group 18-25 years and 58 years and above were the least in terms of respondents. The table also indicate that 40% of the participants has 4-6 years of experience followed by 37% with more than 10 years working experience. Only 10% has 1-3 years of experience.

4.3. Technology Implementation and Use

Table 4.3 Technology use

Technology used	Frequency	Percent
Automated/robotic systems	3	8
Virtual reality (VR) or Augmented reality	8	20
Digital management systems	2	5
Internet of Things	5	13
Digital management systems	9	23
Automated/robotic systems	2	5
Wearable technology, Polystyrene blocks	3	8
Polymer stabilizers	6	15

Results show that, 23% use Digital management systems, followed by 20% of the participants who use Virtual reality (VR) or Augmented reality. About 15% of the participants use polymer stabilizers, whereas, 13% only use internet of things. About 8% use only Automated/robotic systems and Polystyrene blocks whilst, 5% of the participants use Automated/robotic systems respectively.

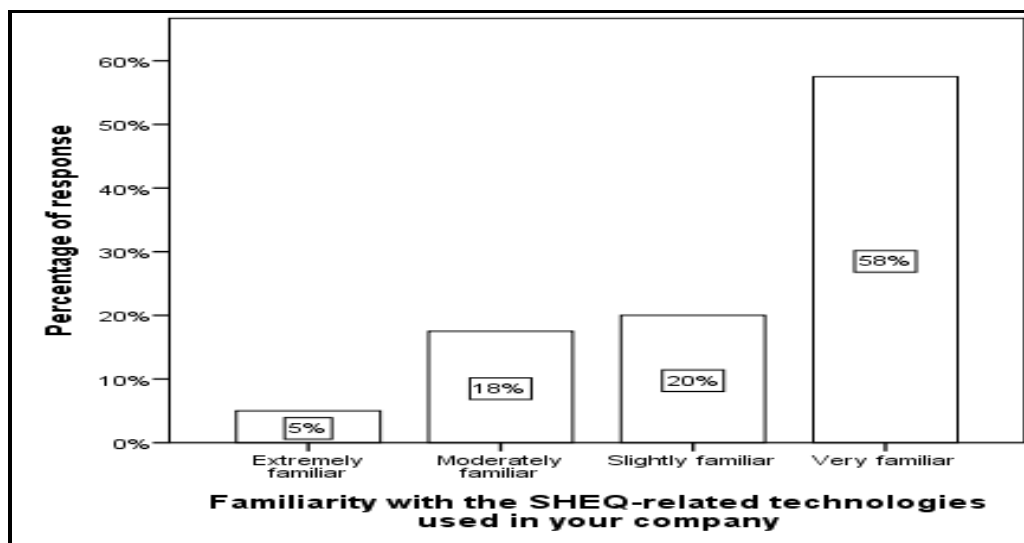


Figure 4.3.1: Familiarity with SHEQ-Related technologies used

Majority (58%) are very familiar with the SHEQ-related technologies used at the company followed by 20% who are slightly familiar and 18% moderately familiar whilst, the least (5%) are extremely familiar

Table 4.3.1 Frequency of interacting with or use SHEQ related technologies

Response

Frequency of use	Frequency	Percent
Daily	30	75.0
Rarely	4	10.0
Weekly	6	15.0

Most (75%) of the participants stated that they interact with SHEQ related technologies on a daily basis, whereas, 15% interact with SHEQ related technologies on a weekly basis and only 10% rarely interact with SHEQ related technologies.

4.4 Impact of Technology on Safety, Health, Environment, and Quality

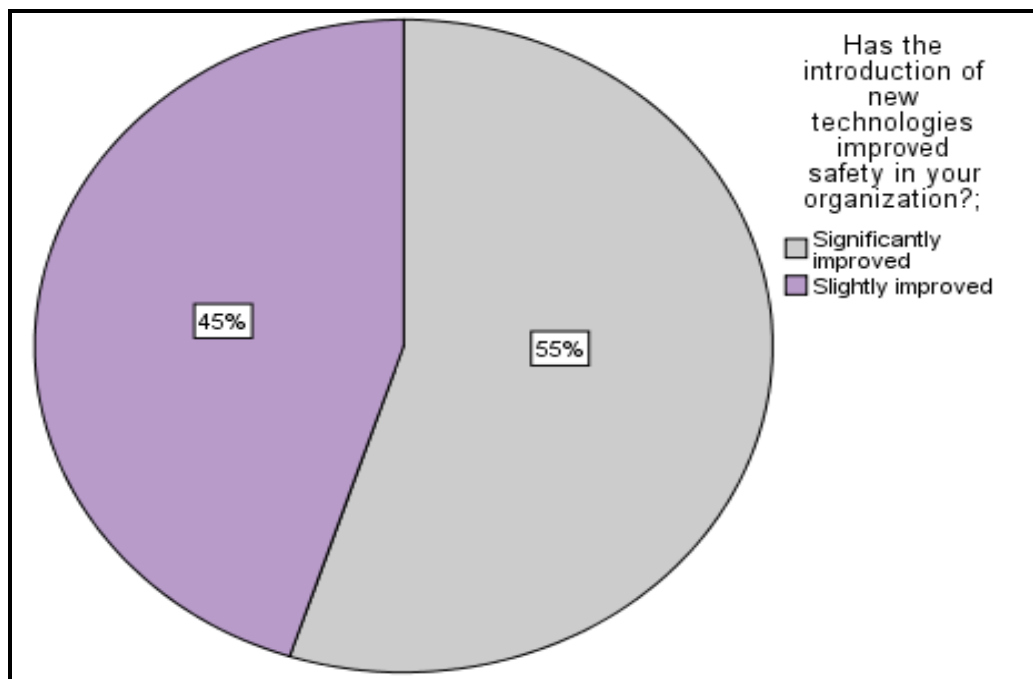


Figure 4.4 Perception on the impact of technology on SHEQ

Majority of the participants were of the view that technology has slightly improved Safety, Health, Environment, and Quality of the organization and only a few (45%) were of the opinion that it has significantly improved SHEQ.

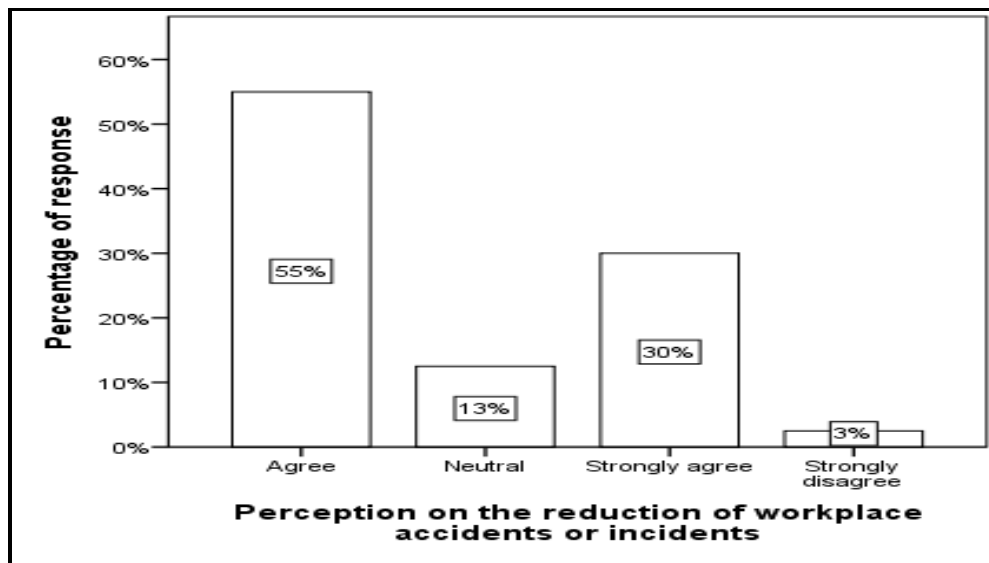


Figure 4.4.1: Perception on the reduction of workplace accidents

Results show, 55% agree that accidents or incidents at the workplace reduced due to SHEQ relayed technologies, 30% strongly agree whilst 13% were neutral and only 3% strongly disagree.

Table 4.4 Impact of Technology on Safety, Health, Environment, and Quality

Questionnaire item	Frequency	Percent
Do you believe that current technological innovations have positively impacted employee health and well-being?		
Maybe	5	13
Yes	35	87
In your experience, has technology improved the quality of products or services?		
Maybe	3	7
Yes	37	92
Has environmental monitoring become more effective since the adoption of new technologies?		
Agree	22	55.0
Neutral	4	10.0
Strongly agree	13	33
Strongly disagree	1	2

Majority of participants, 87%, agreed that current technological innovations have positively impacted employee health and well-being whereas, only 13% were uncertain. In addition, 93% agreed that, technology has improved the quality of products or services and only 7% were uncertain. Results also

indicate that, 87.5% agree that environmental monitoring become more effective since the adoption of new technologies, whilst, 10% were neutral and only 2% strongly disagree.

4.5 Challenges in implementing new technologies for SHEQ management

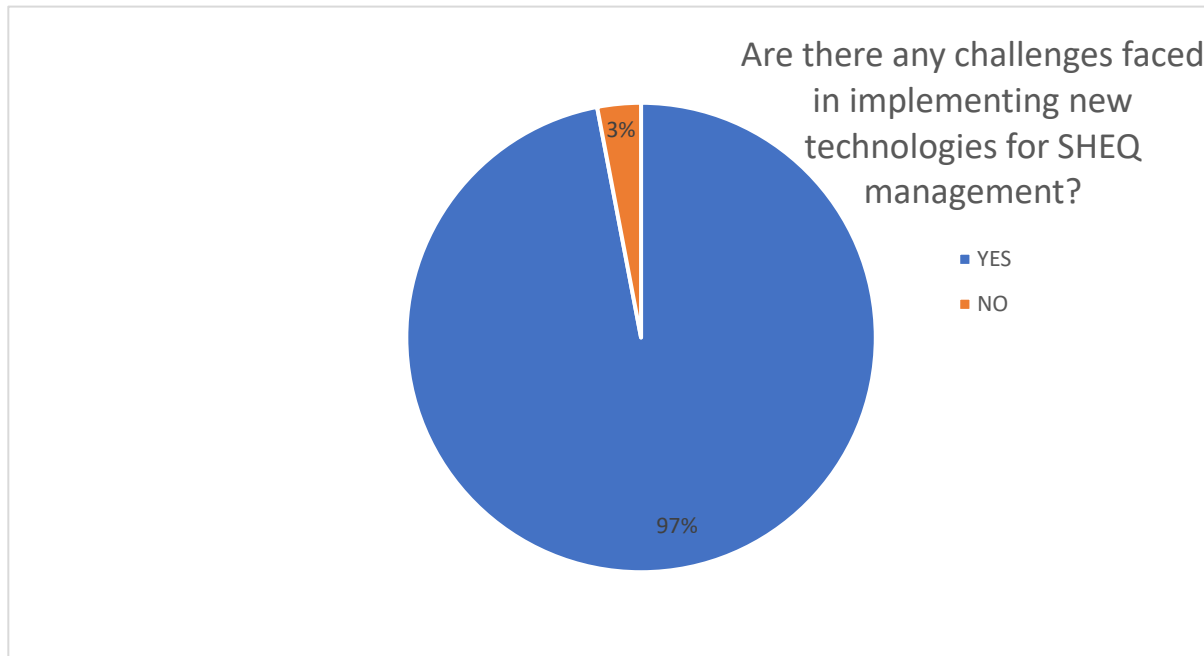


Figure4.5: Perceptions on Challenges in implementing new technologies for SHEQ management

Majority (97%) agree that there are challenges in implementing new technologies for SHEQ management and only a few disagree.

Table 4.5 Most common challenges

Challenges	Frequency	Percent
High costs of technology acquisition	22	55
Lack of technical skills	29	72
Limited infrastructure or connectivity	19	47
Lack of training	39	97
Resistance to change among staff	23	57

The most common challenge faced in relation to implementing new technologies for SHEQ is lack of training as highlighted by 97% of participants followed by resistance to change, high cost of technology acquisition, lack of technical skills and limited infrastructure or connectivity,

Table 4.5.1 Table 4.5 Most common challenges

Questionnaire item	Frequency	Percent
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Do you agree that emerging technologies have increased the overall quality standards in your organization?		
Agree	19	47
Neutral	5	12
Strongly agree	15	37
Strongly disagree	1	2
Do you think that further technological innovations will continue to improve SHEQ management in Harare?		
Maybe	12	30.0
Yes	28	70.0
Would your organization consider investing more in emerging technologies for SHEQ purposes in the future?		
Maybe	5	12
Yes	35	87

Out of 40 participants, 34 (85%) agree that emerging technologies have increased the overall quality standards in the organization, whereas, 12% were neutral and only 2% strongly disagree. Results also show that, 70% of the participants agree that further technological innovations will continue to improve SHEQ management in Harare. Majority, 87% agree that the organization would consider investing more in emerging technologies for SHEQ purposes in the future.

4.6 The relationship between innovations and SHEQ management

The researcher used SPSS to calculate the significant impact of Technological innovations within city of Harare on SHEQ management. Hence the test was conducted using linear regression where, technological innovations was the independent variable and SHEQ management was the dependent variable. Thus, the participants were asked to respond whether technological innovations affect SHEQ management or not and their responses were compared. The test was done at 95% confidence level ($p=0.05$). the results are shown in table 4.7 below

Table 4.6 Relationship between technological innovations and SHEQ management

R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					
				R Square Change	F Change	df1	df2	Sig. Change	F
0.796 ^a	0.750	0.766	0.221	0.750	219.214	1	40	0.000	

a. Predictors: (Constant) technological innovations

Results in table 4.4 indicate that there is a strong relationship between technological innovations and SHEQ management ($R^2=0.750$). Thus, 75% of the participants agreed that technological innovations affect SHEQ management. Therefore, the research accepts hypothesis which stated that there is a significant relationship between Technological innovations within city of Harare and SHEQ management.

4.7 Summary

The chapter focused on data presentation and analysis. The researcher used descriptive and regression statistics to analyse the effect SHEQ related technologies on SHEQ management. The researcher used tables, charts, graphs to present study results. The following chapter will discuss and analyse the results.

CHAPTER 5: DISCUSSION AND ANALYSIS

5.1 Introduction

This chapter analyzes the results regarding the impact of new technologies on Safety, Health, Environment and Quality (SHEQ) management in construction companies located in Harare. It considers social and demographic factors, technology application practices, perceptions regarding impacts, encountered problems, and data-based correlation calculated through regression analysis. It aims to detail the degree at which innovation affects SHEQ outcomes such as accidents reduction and organizational performance enhancement.

5.2 Demographic Context and Technology Adoption.

The participants included slightly more males (55%) than females (45%), showing a fairly balanced gender mix. This means that both male and female employees from the participating organizations engage in some SHEQ-related functions, activities or decision-making processes. While gender diversity is imbalanced, this can foster acceptance and implementation of SHEQ technologies because diverse teams often lead to innovative solutions.

This age distribution reflects stability and accumulated expertise within an organization. Embracing change and innovation however remains questionable, as a significant share (30%) falls within the 42-49 age bracket while 17.5% is between 34-41 years old. Moreover, older workers tend to have greater work experience which aligns with the fact that 37.5% of respondents reported having over ten years of experience suggesting well-informed responses shaped by considerable industry experience.

More senior coworkers may affect how new technologies are adopted and integrated, whether as advocates or hesitant adopters. Understanding and accepting change champions is likely to be based on some appreciation of the technology's usefulness gained over time. Concerning technology adoption, a noteworthy proportion utilizing management systems (23%) and virtual/augmented reality (20%) indicate that firms are adopting sophisticated digital technologies. Management systems have a broad range of accessibility and scalability which explains their high adoption rate. On the other hand, robotics as well as VR/AR require heavier capital expenditures which could account for their lower adoption rates.

A majority 58% of respondents claim to be very familiar with SHEQ related tools suggesting a deep familiarity among both employees and managers regarding available resources. The rest can be

classified as slightly or moderately familiar, while only 5% claim extreme familiarity. This pattern contributes to greater awareness but reflects positive learning outcomes on organization training programs that can still improve knowledge distribution overall. Additionally, this supports the significant 75% of participants who report daily interaction with SHEQ technologies demonstrating significant frequent usage participation in these activities. A smaller portion equal to 15% interact on a weekly basis; only 10% engage infrequently demonstrating daily engagement for most users deploying these technologies into workflows.

5.3 Perceived Impact of Technology on SHEQ.

The information on perceptions concerning the effects of technological innovations on Safety, Health, Environment, and Quality (SHEQ) reveals how both employers and employees perceive technology's effectiveness in improving workplace safety, environmental stewardship, and the overall quality of products or services. Most respondents think that technology has improved SHEQ only to some extent; however, 45% believe technology has very much SHEQ.

Improvements could be gradual over time instead of immediate as some may expect. Companies may still be working toward achieving full implementation or integration. This indicates positive perceptions overall but also suggests that a lot of people perceive further opportunities for improvements which can be captured. The labels of “significant” and “slight” improvements are often subjective based on personal experience or the prevailing organizational culture.

On the reduction of workplace accidents, 85% hold positive perceptions with 55% agreeing and 30% strongly agreeing that workplace accidents have decreased due to SHEQ technologies suggesting overwhelming consensus regarding safety advancements. Research supports this claim as many studies point out that automation and real-time monitoring systems help reduce human error (Haleem 2024). The decrease in accidents highlights the usefulness of implementing such technologies.

Just 13% are unsure, while a significant 87% of respondents think that technological advancements have a positive effect on workers' health and well-being. This high degree of agreement shows that people believe technology can help create safer and healthier workplaces. Furthermore, 87.5% of respondents agreed that environmental monitoring has improved in effectiveness. Technology integration is seen as advantageous for organizational outputs, as evidenced by the resounding 92% of respondents who agree that technology has improved the quality of goods or services.

5.4 Implementation of Technology

Notwithstanding favorable opinions, the data shows significant obstacles, particularly a lack of technical skills (72%), and training (97%). Integration efforts are further hampered by high costs (55%) and resistance to change (57%). These difficulties imply that even though businesses are dedicated to using technology, capacity-building and resource allocation are still crucial areas that require focus in order to optimize gains. This high percentage highlights a prevalent problem with technology adoption, businesses frequently purchase new tools without properly training employees, which results in underutilization or ineffective implementation (Kraus et al., 2020).

Staff members might not be competent or confident enough to use new systems successfully without the right training. Staff resistance (57%) points to behavioral or cultural barriers that may have their roots in unfamiliarity, fear of losing one's job, or doubts about the advantages of technology. In technology projects, change management is frequently undervalued. The fact that 55% of respondents mentioned expenses draws attention to the financial limitations that organizations face, particularly in developing or resource-constrained environments like Harare.

Training, software, and hardware can be prohibitively expensive initially. Nearly half (47%) report infrastructure problems, such as unstable internet connectivity or power supply, which are crucial for digital solutions, particularly in developing regions. 72% of respondents mention this difficulty, indicating a skills gap that can impede technological integration and maintenance. These difficulties imply that a multifaceted strategy tackling financial, infrastructure, and human resource barriers is necessary for the successful integration of new technologies in SHEQ management. It also emphasizes the necessity of change management techniques and capacity building (Davis & Luthans, 2020).

5.5 Statistical Relationship Between Technology and SHEQ Management

Technology innovations and SHEQ management have a strong and significant relationship ($R^2 = 0.75$), according to the linear regression analysis, with a p-value of 0.000 indicating high statistical significance at the 95% confidence level. A strong correlation is indicated by the R-value (0.796), which suggests that technological advancements account for 75% of the variation in SHEQ management results. The impact of technological advancements on SHEQ is further supported by the significant F-change statistic.

This demonstrates how improvements in technology can improve data collection, risk assessment, compliance monitoring, and incident reporting, all of which contribute to better environmental and safety outcomes (Nguyen et al., 2021). IoT sensors, data analytics, and real-time monitoring systems

are examples of innovations that give businesses greater control and proactive management capabilities.

5.6 Conclusion

The results show how important technology advancements are to enhancing quality, safety, health, and environmental performance in Harare's organizations. The benefits of technology-driven SHEQ strategies are highlighted by the reported decrease in workplace accidents as well as the perceived and statistically supported positive impact. To fully realize these advantages, however, implementation issues, in particular, those related to infrastructure and training must be resolved. According to this analysis, the implementation of new technologies greatly improves SHEQ management in Harare. Organizations are aware of the advantages and hopeful about new developments, but in order to maintain and increase these gains, a strategic focus on capacity building, cost control, and change management will be essential.

5.7 Recommendations

1. Encourage regulatory and policy frameworks that facilitate the adoption of technology.

Policymakers should create and implement precise rules and guidelines that promote creativity in SHEQ management in order to make it easier to integrate emerging technologies. Incentives like tax breaks or certification programs for businesses implementing cutting-edge environmental and safety technologies could be part of this, which would encourage the adoption of new technologies.

2. Development of Skills and Capacity.

Industry stakeholders should fund focused training initiatives to improve managers' and employees' capacity to use new technologies, given the skills gaps and change aversion noted as obstacles. Collaborations with industry associations and technical institutions can support ongoing professional development, guaranteeing that staff members are capable and self-assured in implementing cutting-edge SHEQ.

3. Encourage cooperation and involvement from stakeholders

Promoting cooperation between construction companies, technology suppliers, authorities, and employees can enhance comprehension and resolve issues pertaining to the adoption of technology.

Platforms for engaging stakeholders can be set up to promote information exchange, feedback gathering, and cooperative problem-solving, which will boost support and lessen opposition to change.

4. Adapt Technical Solutions to Regional Situations

Technologies should be modified to accommodate the economic, regulatory, and infrastructure realities of the building industry in Harare. To increase the likelihood of successful implementation, developers and suppliers should collaborate closely with local businesses to create solutions that are user-friendly, reasonably priced, and compatible with current procedures.

5. Put in place frameworks for long-term monitoring and evaluation

Construction companies and regulatory agencies should set up methodical monitoring and assessment systems to guarantee long-term improvements. This would entail routine evaluation of the long-term effects of technology advancements on SHEQ results, enabling iterative enhancements and evidence-based decision-making.

6. Create a Comprehensive SHEQ Management Strategy

Using Technology Instead of considering technology tools as stand-alone solutions, organizations should incorporate them into their overall SHEQ management systems. With the help of real-time data, predictive analytics, and automated reporting, this integration can foster a culture of ongoing safety and quality improvement.

7. Increase Knowledge and Encourage a Culture of Safety and Innovation

To emphasize how technological advancements can improve safety, health, environmental sustainability, and quality standards, campaigns and awareness initiatives should be started. Businesses can be encouraged to accept technological change by fostering a culture that values innovation and proactive SHEQ management.

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APPENDICES

APPENDIX 1: Research Survey Questionnaire

My name is Natasha Nyaradzo Marufu. I am an undergraduate student doing a Degree in Safety, Health, and Environmental Management Bindura University of Science Education. I am undertaking a research project titled, “An analysis on the impact of technology introduction on safety, health, environmental and quality management, A case of Emerging Trends and Innovations, Harare”. As part of the data collection procedure of this academic investigation, your participation in this questionnaire is significantly necessary. Please note that your participation in this questionnaire, is also very important. Please note that your answers will be exclusively used for academic purposes only and your privacy and confidentiality needs will be respected.

INSTRUCTIONS TO PARTICIPANTS

- *Tick the answer and fill in where ever possible.*
- *Never put your name on any portion of the page*

SECTION A: SOCIO-DEMOGRAPHIC CHARACTERISTICS

1) Age (years): 18-25 ☐ 26-33 ☐ 34-41 ☐ 42-49 ☐ 50-57 ☐ 58+ ☐

2) Sex: Male ☐ Female ☐

3) Are you directly involved in or impacted by the use of new technologies in your work?

Yes ☐ No ☐

4) How long have you been working at this company?

Less than 1 Year ☐ 1 – 5 years ☐ 5 – 10 years ☐ Over 10years ☐

5) Which department or team are you primarily associated with?

SECTION B: TECHNOLOGY IMPLEMENTATION AND USE		
Number	Question	Answers
7.	Which of the following technologies has your company implemented?	☐ Digital management systems ☐ Internet of Things (Sensors for monitoring) ☐ Wearable technology (e.g. smart helmets) ☐ Automated/robotic systems ☐ Virtual reality (VR) or Augmented reality ☐ Others -----
8.	On a scale of 1 to 5, how familiar are you with the SHEQ-related technologies used in your company?	1 - Not at all familiar 2 - Slightly familiar 3 - Moderately familiar 4 - Very familiar 5 - Extremely familiar
9.	How frequently do you interact with or use these technologies in your daily work related to SHEQ?	☐ Daily ☐ Weekly ☐ Monthly ☐ Rarely ☐ Never
SECTION C: IMPACT ON SAFETY MANAGEMENT		
10.	To what extent do you agree or disagree with the following statement: "Technology has improved workplace safety in my company"	1 - Strongly Disagree 2 - Disagree 3 - Neither Agree nor Disagree 4 - Agree 5 - Strongly Agree
11.	How has technology specifically impacted safety incident reporting and investigation in your experience?	----- ----- ----- ---

12.	Have you observed any new safety risks or challenges introduced by the use of technology? If yes, please provide an example	-----
13.	How has technology influenced safety training and awareness programs?	----- -----
SECTION D: IMPACT ON HEALTH MANAGEMENT		
14.	In what ways, if any, has technology helped in identifying or mitigating health risks in the workplace?	----- -----
15.	Have you experienced or observed any negative impacts of technology on employee health (e.g., increased screen time, stress from monitoring)?	----- -----
16.	Overall, what do you see as the biggest positive impact of technology on SHEQ management in your company?	----- -----
17.	What do you see as the biggest challenge related to the use of technology in SHEQ management?	----- -----
18.	To what extent do you feel your company provides adequate training and	1 - Not at all adequate 2 - Slightly adequate 3 - Moderately adequate

	support for using SHEQ-related technologies?	4 - Very adequate 5 - Extremely adequate
19.	Is there anything else you would like to share about the impact of technology on SHEQ management in your company?	----- -----

APPENDIX 2: Similarity Page

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